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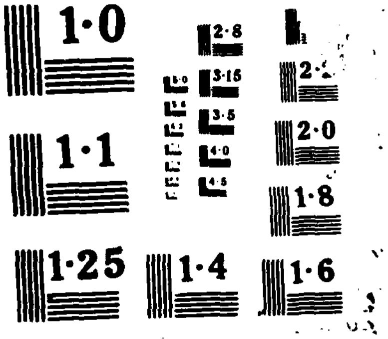
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2WW/TN-88/002

Maximum and Minimum Temperature Forecasting in Europe

by Lt. Col. Donald L. Best

January 1988

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19. Abstract: A look at how to forecast maximum and minimum surface temperature in Europe. The traditional approaches are presented with strengths and weaknesses. A means to tailor your own 850 mb climatological temperatures to produce the forecasts is introduced with an example.

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INTRODUCTION

How many ways are there to forecast maximum and minimum temperatures? Does your favorite CONUS-based procedure work here in Europe? The answers are "many" and "not necessarily," respectively. Unless your predecessors made an extra effort to document the best temperature forecasting technique in your TFRN, most of you probably don't know which is the best technique for your station to use. I am publishing this TN in hopes of invigorating your search for that best technique. Most of these techniques you will already recognize, but perhaps you really haven't thought much about their individual strengths and weaknesses. I've tried to do that for you in this TN. I asked our 2 WW units to comment and contribute to this TN--and they did. Their contributions include a discussion in Appendix A, some edits within the TN, and a study report by MSgt Roger L. Lowe of Det 15, 28 WS, in Appendix B.

Regardless of which technique or combination of techniques you use, remember that a temperature forecast is just as important to some of your customers as ceiling and visibility forecasts are to others. A professional weather forecaster gives his or her best possible shot on all forecast elements--don't we? Maybe this TN will give you a clearer aim at one of those elements.

TABLE OF CONTENTS

MAXIMUM AND MINIMUM
TEMPERATURE FORECASTING IN EUROPE

I. TRADITIONAL TECHNIQUES

A. MAXIMUM TEMPERATURE

1. Heating Depth to 850 mb Accounts for an estimated depth of atmosphere that on the average over the year will be observed at time of maximum afternoon heating.

a. Procedures:

(1) Use the most recently plotted upper air sounding which is considered representative for the forecast location in question.
(2) Follow the dry adiabat from the observed 850 mb temperature to the surface.
(3) The resulting surface temperature is the forecast maximum temperature.

b. Strengths:

(1) A simple and easy to remember procedure.
(2) A fast estimate.

c. Weaknesses:

(1) Does not account for air mass changes since the time of the sounding.
(2) Does not account for cloudiness which may limit the amount of radiative heating and the depth of the atmosphere heated thereby.
(3) The 850 mb rule is based on a gross yearly average. Therefore, it does not account for seasonal or regional effects. For example, in Europe north of the Alps, this rule only works from about mid-March through mid-September.

2. Numerical Prog Thickness

a. Procedures:

(1) Determine present overhead thickness value.
(2) Determine if changes in thickness values will occur by maximum heating time using numerical model facsimile products.
(3) Estimate geographical source of new thickness values and examine surface maximum temperatures in the source region (use either surface observation data or surface analysis plots).
(4) Use reasonable area averaging, terrain height differences, and expected changes in cloudiness to decide upon a reasonable expected maximum temperature over the forecast location.

b. Strengths:

(1) Accounts for atmosphere changes.
(2) Accounts for analysis of actual surface temperature being observed within the atmosphere which is expected later to be over the forecast station.
(3) Fairly simple.
(4) Permits forecaster judgment (e.g., location experience, meteorological knowledge, daily models accuracy, etc.)
(5) An excellent tool for consensus decisions.

c. Weaknesses:

(1) Depends on facsimile products that may be late, missing, or in error.
(2) Depends on individual skill, thus being less objective and reproducible from forecaster to forecaster.
(3) Does not account for temperature changes due to solar heating over the land, if the determined source area is over the water, i.e., Atlantic Ocean or North Sea.

3. Use of Trajectory Data

a. Procedures:

(1) Estimate gradient and 850 mb temperatures expected over station at time of maximum heating using the temperature forecasts of the FJ( ) KGWC. If available, pick a trajectory forecast time which would match an available plotted skew-t (e.g., the 12Z FJ( )KGWC 12-hr line would match a 00Z sounding).
(2) On the thermodynamic chart, follow the dry adiabat for both temperatures down to the surface. A forecast temperature window will result, bound by the associated surface temperatures.
(3) Compare the trajectory forecast upper air values to your representative skew-t values to calibrate this procedure (e.g., if the sounding shows 2 degrees colder than forecast, use 2 degrees as an adjustment to step (2) above).
(4) After adjusting the initial forecast temperature window, use your best judgment as to where within this window the maximum temperature is most likely to be.
(5) Special Considerations:

(a) During the winter or during expected cold air advection lean toward the lower window value.
(b) During the summer or during expected warm air advection lean toward the higher window value.
(c) Before choosing any value, judge whether the trajectory forecasts themselves are reasonable and adjust your thinking accordingly.

b. Strengths:

(1) Accounts for changes of atmospheric conditions.
(2) Accounts for changes due to seasonal effects.
(3) Can catch the sudden cooling or warming events.
(4) Permits forecaster judgment as to other effects that may come into play.
(5) Gives a window of possible values instead of only one forecast value.

c. Weaknesses:

(1) Teletype product may be late, missing, garbled, or in error.
(2) Depends on ability of trajectory model to accurately depict future expected movements and cooling/heating of air parcels by the time these air parcels arrive over station.
(3) A more time-consuming procedure than most others.

4. Climatological Diurnal Curves. USAFETAC produces a Diurnal Dry Bulb and Dew-Point Temperature Curves report for most stations. Each 2 WW unit should have such a report near the forecast counter. This report is stratified by month, ceiling, and wind speed. It is fairly self explanatory. If you have it, try it.

B. MINIMUM TEMPERATURES

1. <u>850 mb Rule</u>

a. Procedures:

(1) Use the most current and representative plotted upper air sounding for the forecast location in question.

(2) Follow the moist adiabat from the 850 mb dew point temperature to the surface.

(3) The resulting surface temperature is the forecast minimum temperature.

b. Strengths. Same as MAXIMUM TEMPERATURE, para A1b.

c. Weaknesses. Same as MAXIMUM TEMPERATURE, para A1c.

Note: This rule does not work if strong subsidence creates an inversion below the 850 mb level.

2. <u>Numerical Prog Thickness</u> Use the same procedures as for forecasting maximum temperatures, but inspect for the source region's minimum temperatures and associated effects due to radiational cooling. (See MAXIMUM TEMPERATURE, para A2).

3. <u>Use of Trajectory Data</u>

a. Procedures:

(1) Estimate gradient and 850 mb temperature and dew point temperature expected over the forecast station at time of maximum cooling using the FJ( ) KGWC bulletin.

(2) Using a thermodynamic chart and the temperature and dew point temperature for each level, determine the associated LCLs. Follow the moist adiabat from each LCL to the surface. A forecast temperature window will result bounded by the two resulting surface temperatures.

(3) Calibrate the window values (see MAXIMUM TEMPERATURE, para A3a(3) through (4)).

(4) Make a forecast in much the same way as rules for trajectory maximum temperatures (see MAXIMUM TEMPERATURE, para A3a(5) through (6)).

b. Strengths. Same as MAXIMUM TEMPERATURE, para A3b.

c. Weaknesses. Same as MAXIMUM TEMPERATURE, para A3c.

4. <u>Afternoon Dew Point at Time of Maximum Heating</u>

a. Procedure: Forecast the next morning's minimum temperature to be equal, or slightly warmer, than the dew point observed at time of maximum heating.

Note: If skies are clear and winds are calm, minimum temperatures will be 2° to 4° C lower than the afternoon dew point during the period September through March at all stations located in flat lands or valley floors.

b. Strengths

(1) A reasonable estimate based on the assumption that the minimum temperature cannot be lower than the dew point if the air mass and atmospheric moisture don't change.

(2) A fast estimate.

c. Weaknesses

(1) Does not account for air mass changes.

(2) Does not account for cloudiness which may inhibit the radiative cooling process.

II. COUNTER AID FOR MAX/MIN TEMPERATURE FORECASTING

A. MAXIMUM.

1. 850 mb Rule. Bring 850 mb temp to surface using the dry adiabat lapse rate. If relative humidity is over 95 percent, then use the moist adiabat instead.

2. Numerical Progs. Determine originating source of air overhead at time of maximum heating. Determine the average max temp that occurred the day before in that source region. Modify those observed temperatures according to changes in elevation, snow cover, cloud cover, etc.

3. Trajectory Bulletin. Use the FJ( ) KGWC forecasts of the temperatures at the gradient and 850 mb levels expected to be overhead at maximum heating. Bring both temperatures (use a thermodynamic chart) down to the surface using the dry adiabat lapse rate--a forecast window will result. Use your best judgment, considering the meteorological situation, as to the preferred single value within this forecast window.

4. Climatological Diurnal Curves. Use the USAFETAC wind/cloud cover stratified temperature curves.

B. MINIMUM.

1. 850 mb Rule. Bring the 850 mb dew point temperature to the surface using the moist adiabat lapse rate.

2. Numerical Progs. See para A1b above and use the same procedures, but for minimum temperatures.

3. Trajectory Bulletin. Use the FJ( ) KGWC forecasts of the temperature and dew point temperature at the gradient and 850 mb levels. For each level lift both of their respective LCLs then follow the moist adiabat lapse rate from their LCLs to the surface--a forecast window of surface temperatures will result. Use your best meteorological judgment to pick a preferred single value within this window.

4. Afternoon Dew Point Rule. The next morning's minimum temperature will be the same as the dew point temperature observed at the time of maximum heating. When the max temp is recorded over more than one observation time, use the first observed max temp's dew point for this rule.

III. TAILORED EQUATIONS FOR MAX/MIN TEMPERATURE FORECASTING

A. TECHNIQUE INTRODUCTION. Perhaps the most popular rules used to forecast maximum and minimum surface temperatures are the "850 rules." There are some weaknesses in using the 850 mb temp/dew point blindly--particularly in Europe. For example, in our moist low-level climate, bringing the 850 mb temp to the surface using a dry adiabatic lapse rate will often over-forecast the maximum. Some forecasters have noted that using the moist adiabatic lapse rate works better. Another weakness about the 850 rule is that it was invented (like so many other simple rules) somewhere else and disregards any seasonal variations in actual heating depths (e.g., perhaps the 900 mb level is better in December and 800 mb in July at your station). Finding preferred heating levels at each forecast location is difficult (not impossible) because the climatological data required may not be available. Therefore, an alternate procedure is presented here which takes advantage of the more abundant climatological data available for the 850 mb level. The procedure is simple to develop and easy to use on a daily basis.

B. STEPS TO CONSTRUCTING LOCAL FORECAST EQUATIONS

1. Use work sheets provided in Atch 1 (MAX) and Atch 2 (MIN). Examples are provided in Atch 4 and 5.

2. Log under the "X" column the mean monthly 850 mb temperature (Atch 1) and dew point temperature (Atch 2). These can come from your Standard Summary Package or climo charts. Temperatures may also be in any units convenient to you (the example uses degrees Celsius).

3. Log under the "Y" column the mean monthly maximum (Atch 1) and minimum (Atch 2) surface temperatures at your station.

4. Complete the column cross product multiplications (e.g, XY = X times Y) and squaring (e.g., X^2 = X times X).

5. Fill in the totals row (e.g., E = sum of X (Jan) thru X (Dec)).

6. Complete mathematical computations at bottom of worksheet by substituting appropriate row-total values as guided by letters.

7. Compute monthly correction factors by using Atch 3.

C. OPERATIONAL USE OF TAILORED EQUATIONS

1. Use either the most recent and representative thermodynamic chart, trajectory bulletin, or prog charts to determine 850 mb temperature at time of max heating and 850 mb dew point temperature at time of min temp.

2. Apply forecast equations to these 850 temps and add the monthly correction factor.

3. Subjectively subtract or add to move the final value any reasonable amount based on expected non-normal behavior of the daily weather. For example, low overcast skies may convince you to lower the maximum temperature and raise the minimum temperature forecasts. Or, unusually clear skies may convince you to do the opposite. However, remember that in the long run the untouched numbers will most likely verify the best unless the forecaster is very skilled at predicting the non-normal daily weather changes.

MAXIMUM TEMPERATURE EQUATION DEVELOPMENT WORKSHEET

MONTH	Average Max Surface Temp Y	Average 850mb Temp X	XY	X^2
JANUARY				
FEBRUARY				
MARCH				
APRIL				
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				
TOTALS.........			A=	B=
AVERAGES (DIVIDE BY 12)	C=	D=	N/A	E=

FORECAST EQUATION: MAX Fcst = a + b* 850mb Temp

Where .... b = (A - 12*C*D)/(B - 12*D*D) =

a = C - b*D =

Atch 1

MINIMUM TEMPERATURE EQUATION DEVELOPMENT WORKSHEET

MONTH	Average Min Surface Temp Y	Average 850mb Dew Point X	XY	X^2
JANUARY				
FEBRUARY				
MARCH				
APRIL				
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				
TOTALS.........			A=	B=
AVERAGES (DIVIDE BY 12)	C=	D=	N/A	E=

FORECAST EQUATION: MIN Fcst = a + b* 850mb Temp

Where .... b = (A - 12*C*D)/(B - 12*D*D) =

a = C - b*D =

Atch 2

MONTHLY ADJUSTMENT FACTORS DEVELOPMENT WORKSHEET

MONTH	850mb Temp/Dew Pt (X)	Surface Fcst using equation (YF)	Actual Surface Temperature (Y)	Adjustment Factor (Y - YF)
MAXIMUM				
JANUARY				
FEBRUARY				
MARCH				
APRIL				
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				
MINIMUM				
JANUARY				
FEBRUARY				
MARCH				
APRIL				
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				

Atch 3

MAXIMUM TEMPERATURE EQUATION DEVELOPMENT WORKSHEET

MONTH	Y Average Max Surface Temp	X Average 850mb Temp	XY	X^2
JANUARY	3	-3	-9	9
FEBRUARY	5	-3	-15	9
MARCH	9	-.5	-4.5	.25
APRIL	14	1	14	1
MAY	18	6	108	36
JUNE	21	9	189	81
JULY	23	11	253	121
AUGUST	23	10	230	100
SEPTEMBER	19	8	152	64
OCTOBER	14	5	70	25
NOVEMBER	8	1.5	12	2.25
DECEMBER	4	-1	-4	1
TOTALS.........	161	44	A= 995.5	B= 449.5
AVERAGES (DIVIDE BY 12)	C= 13.417	D= 3.667	N/A	E= 37.458

FORECAST EQUATION: MAX Fcst = a + b* 850mb Temp

Where .... b = (A - 12*C*D)/(B - 12*D*D) = 1.406

a = C - b*D = 8.261

Atch 4

MONTHLY ADJUSTMENT FACTORS DEVELOPMENT WORKSHEET

MONTH	850mb Temp/Dew Pt (X)	Surface Fcst using equation (YF)	Actual Surface Temperature (Y)	Adjustment Factor (Y - YF)
MAXIMUM				
JANUARY	-3	4.04	3	-1.04
FEBRUARY	-3	4.04	5	+0.96
MARCH	-.5	7.56	9	+1.44
APRIL	1	9.67	14	+4.33
MAY	6	16.70	18	+1.30
JUNE	9	20.92	21	+0.08
JULY	11	23.73	23	-0.73
AUGUST	10	22.32	23	+0.68
SEPTEMBER	8	19.51	19	-0.51
OCTOBER	5	15.29	14	-1.29
NOVEMBER	1.5	10.37	8	-2.37
DECEMBER	-1	6.86	4	-2.86
MINIMUM				
JANUARY				
FEBRUARY				
MARCH				
APRIL				
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				

Atch 5

Appendix A

SOME FIELD COMMENTS

1. One 7th Weather Squadron unit reviewed the draft TN and believed the 850 mb method to be the best, but felt the maximum temperatures should be advected. As with all forecasting methods or rules, choosing representative upstream data is the first and most often difficult step. Possibly, we should direct our attentions more toward selecting upstream data and then temper our methods and central progs with climo curves.

2. Another unit said that for personal rule-of-thumb methods, there are no forecast verification statistics to validate the methods, but some things can subjectively be said about the dynamic considerations:

a. Both minimum and maximum temperature extremes tend to be muted following passage of a long-wave trough. In this type of synoptic situation, fog or stratus frequently forms, causing the minimum temperature to be near or above the previous day's max dew point. Therefore, the method of using the afternoon dew point at time of maximum heating seems to work very well following the passage of an upper level long-wave trough when forecasting the next day's minimum temperature.

b. Another major concern when forecasting maximum temperature is the dynamic conditions which cause afternoon cumulus clouds and the potential for thunderstorm development. For instance, one forecaster noticed that a high dew point upstream from the station associated with a local southwest low-level wind tends to enhance thunderstorms, even when there is no apparent trigger observed on the numerical progs. The significance is that this would hurt the trajectory method, since the physics are definitely subgrid phenomena. This effect points to another weakness in trajectory method to forecast max/min temperatures: "Can give very misleading estimates when subgrid phenomena such as cumulus are present."

c. Another dynamic factor noticed by one of our forecasters is that following a frontal passage, winds over continental Europe back as one goes from sea to land. The impact: oceanic air is brought over the continent, meaning the forecast temperature for even continental locations should be similar to the forecast for a maritime air mass following a front passage.

Appendix B

CRADDOCK'S MINIMUM TEMPERATURE FORMULA

by MSgt Roger L. Lowe
Det 15, 28 WS

1. INTRODUCTION

While doing a bit of research on the various fog studies available to the Military Weather Forecaster, I stumbled across a minimum temperature study produced by J.M. Craddock and D. Pritchard. The study was included in a paper entitled "Forecasting the Formation of Radiation Fog - A Preliminary Approach." This was a MET RESEARCH PAPER, London, No. 624, 1951.

This report is no longer available locally in its original form but may possibly be on file in the archives at the British Met Office in London.

Craddock evolved a statistical formula based on the 1200Z temp/dew point combined with the mean gradient wind. This formula produced a minimum temperature forecast and was used to construct a temperature curve to aid in forecasting the onset of fog in East Anglia. The formula is restricted to stagnant air mass. Transition situations would not produce an accurate forecast. At first glance the formula appeared to be a bit too complicated, confusing, and difficult to work in order to use it as a quick or first guess guide. A longer look proved the contrary. It is easy and useful. However, to make it appear less confusing, I did round off some numbers and wondered what effect this would have on the actual results. Since I wanted to re-verify the results, I decided to apply the shortened formula to a period of time. I also decided to use forecast surface winds as a primary ingredient, rather than gradient winds.

2. PROCEDURES

Craddock's original formula is:

$.316T + .548D + 2.12 + C$(degrees F)
T = 1200Z Temperature
D = 1200Z Dew point
C = determined from the following table

Mean Gradient Wind	Mean Cloud Amount (octaves)			
	0-2	2-4	4-6	6-8
0-12	-4	-3	-1	0
13-25	-2	0	+1	+2
26-38	-1	0	+1	+2
39-51	+2	+3	+5	

The modified formula is:

$.32T + .55D + 2.12 + C$(degrees F)
T = 1200Z Temperature
D = 1200Z Dew point
C = determined from the following table

Mean Forecast SFC Wind	Mean Forecast Cloud Amount 0-2	3	4-5	6-8
< 10	-3	-2	-1	0
≥ 10	-1	0	0	+1

The modified version seems (I emphasize the word seems) to be slightly simpler to work because of the rounding off and also because the forecaster has only to forecast a wind greater than or less than ten knots.

3. RESULTS

I applied the modified version to 245 days from January through August (using different months from different years). 150 verified to within +/-3°F. That is a total of 61% correct overall. However, during the summer months of June through August, 67 days out of 92 verified for a grand total of 73% correct. The increase in percentage is due to the decrease in fronts working through East Anglia during the summer. A previous paper stated that Craddock's technique was verified in 1969-1970 at RAF Mildenhall. 66 nights were tested and 40 resulted in the +/-3°F leeway. This is 61% correct--the same as the modified version. Craddock's formula tended to forecast too warm of minimum temperatures as on 30 nights of the total the actual minimum was less than forecast. The modified version tended toward the cold side. During the summer months mentioned above 10 were exact, 17 were too warm, and 40 were on the cold side.

4. SUMMARY

In a stagnant situation, using the modified version of the formula in conjunction with the nearest upper air sounding and the temperature curves in the CC tables will give the forecaster a solid first guess for the minimum temperature. The modified version doesn't produce any better results but may be simpler to use and therefore more likely to be used by a busy forecaster. It should be considered as another tool, but not the primary tool, for looking at min temps.

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